NEW FINDINGS IN FIRE PREVENTION AND FIRE FIGHTING OF PV INSTALLATIONS

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ABSTRACT: Fire prevention of PV installations is a key research field of the PV Laboratory of the Berner Fachhochschule[1]. In a comprehensive research project of TÜV-Rheinland (with participation of the PV laboratory of the Berner Fachhochschule) a certain number of fire incidents with and on PV installations had been reported. In the state of Berne, the state owned insurance company "Berner Gebäudeversicherung GVB" started together with the PV Laboratory a three year research project on the topic. The research should lead in practical advices for the firemen and their instructors in the state of Berne[2].
Investigations about the cross interoperability of PV connectors showed that this creates a serious quality problem in PV installations[3]. Through fires on farm houses with roof integrated PV installations, we got aware that, after a fire, a serious amount of silicon particles will be spread other a wide area in the direction of the wind. We investigated the process and analyzed all the particles and their impact on the farmers land. We investigated several aspects of this process and how he has to be treated to avoid problems for the farmer and his animals.
Keywords: Photovoltaics, fire prevention, PV connectors, cross interoperability, silicon particles

1 RESEARCH TOPIC: PV FIRE HAZARD

The PV laboratory of the BFH collaborated on the TÜV-Projekt „PV-Fire Hazard". The final report can be downloaded since 2015 under: www.pvtest.ch[4].

2 RESEARCH ON CROSS INTEROPERABILITY OF PV CONNECTORS

Components of PV installations as PV modules, connection boxes and PV inverters are connected more and more with connectors. The industry developed special "PV – connectors" for that purposes for high DC-voltages up to 1'000 VDC, DC-currents up to 30 ADC and the ambient conditions of a PV installation as radiation, humidity and changing temperatures. The PV market offer several standards or products. Normally these connectors are not interchangeable. The problem are copies of the „standard" connectors. They are normally cheaper than the „original connector". Connections with the „orginal-" and the „copy-" – connector are a "Cross connection". In a diploma work[5] we tested these connections according the industry norm EN50521. We used the PV Laboratory infrastructure and two climate chambers. We measured the connections before and after the artificial aging. All connectors would be checked with a scanning electron microscopy SEM. With that we could investigate the material and the thickness of the layers. With this information we can calculate the life time of the connector.

3 SURVEY BY PV INSTALLERS IN SWITZERLAND

To have an idea how relevant the problem would be, we asked 190 PV installers from Switzerland. 30 Installers sent the questionnaire back (15,8%)[6].

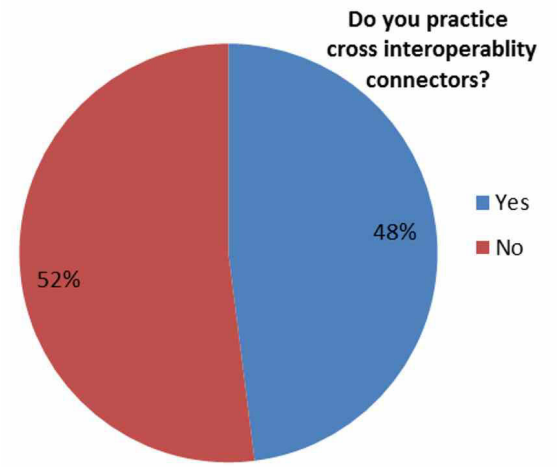

Figure 1: 48% of PV installers in Switzerland practices cross connectors

47% of all installers had problems with connectors. 14% had damaged cross connections. They reported 75% of the problems in the first year of the installation. This is not amazing as the Swiss PV market grows quick in the years 2010-2013 from 40 MWp to over 300 MWp[7].

4 TEST CONFIGURATION FOR CROSS CONNECTION TEST

We choosed connectors with a relevant market share in mid Europe:

- Amphenol
- Lin Yang
- Multicontact
- QC Solar
- SMK
- Tyco
- Weidmüller

Cycle-Test

After the first measurement of the contact resistance, the cycle test will be started according the Norm EN 50521 „Connectors for PV – Systems – safety requirements and tests“. The test cycle includes:

- 30 min in the upper temp. range +85°C +/-2°C;
- 30 min in the lower temp. range of -40°C +/-2°C;
- Transfer time: < 3min;
- cycles: 200.

Humidity-/ heat test

The artificial aging is done by the test conditions:

- Test temperature: +85°C +-/2°C;
- Relative air moisture: +85% +/- 5%;
- Test time: 1000h.

Final measurement

Similar to the initial measurement is the finale measurement. According Norm EN 50521 the resistance should not be higher than 50% of the reference value or not more than 50%. The higher value is allowed.

We used three samples for all the combinations to have enough samples for further tests. The test combinations were:

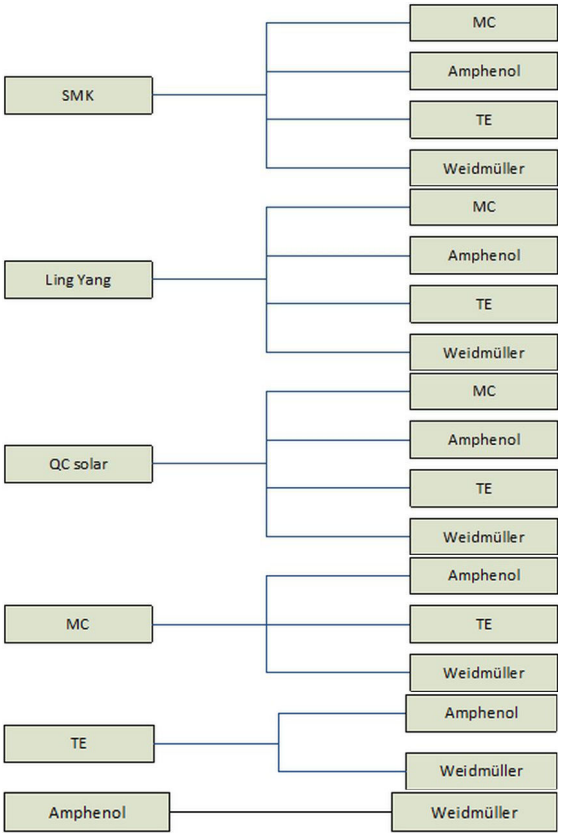

Figure 2: Connector combination for the test

Measurement of the resistance

The resistance test was done according Norm EN 60512-2-2:2013. The current has to be measured in both directions with the formula:

$$\frac{|\Delta U_{Vor} + \Delta U_{Rück}|}{|I_{Vor} + I_{Rück}|} = R_{Brutto}$$

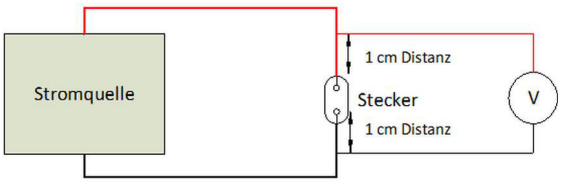

Figure 3: Measurement of the resistance

Results of the measurement before the aging:

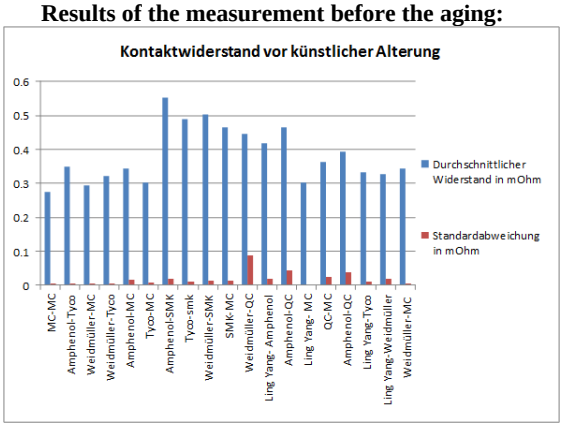

Figure 4: Contact resistance before the artificial aging [mΩ]

The differences in the resistance of the different combinations are relevant, but still in a small band. With the nominal current of 30 A the temperature enhancement is small:

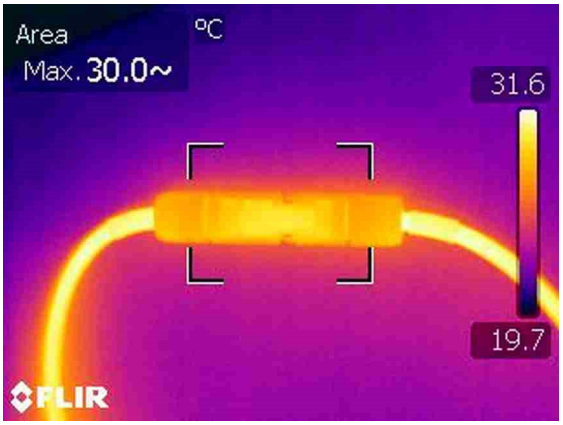

Figure 5: MC-MC connection

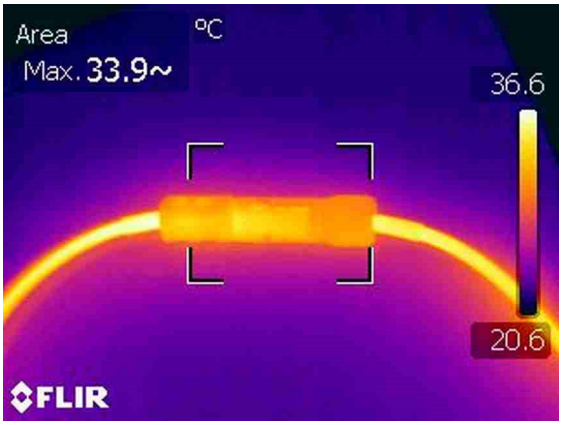

Figure 6: Amphenol-SMK cross connection

Results of the measurement after the aging:

The resistance went up to more than 180%. Many of the cross connections are over the allowed value of 50%. Some of the changes are very significant.

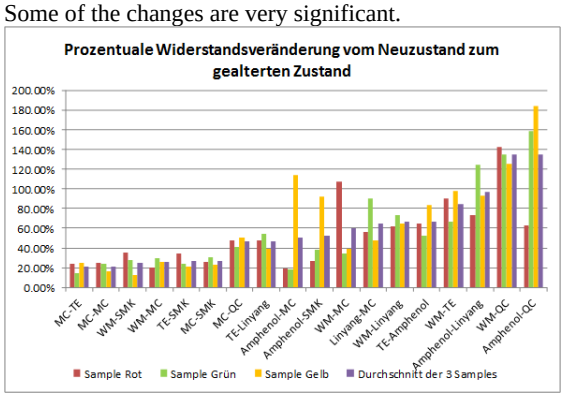

Figure 7: Contact resistance after the artificial aging [mΩ]

An example after the cross connection test after aging shows a drastic enhancement of the temperature which could cause a fire:

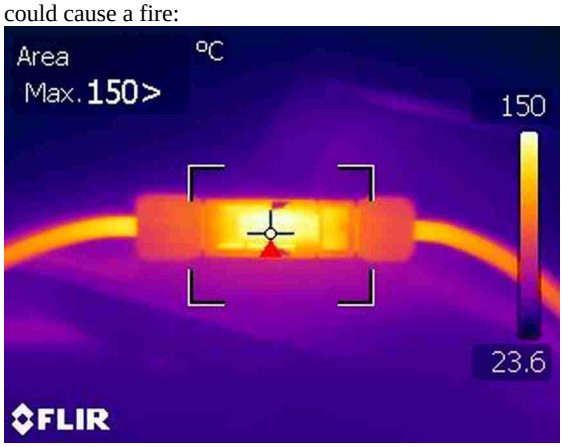

Figure 8: This cross connection after the aging can reach 1500C with nominal current. This could cause a fire!

Practical example: Cross connection failed in the field

In a 131 kWp in-roof installation in Switzerland, in spring 2015 this cross connectors were found. This could cause a fire.

Figure 9: Failed Cross interoperability PV connectors Lumberg-MC of a BIPV-installation

Summary:

Cross connections with different PV connectors must be avoided. It has to be seen as a serious technical deficit and must be replaced. Liability through insurance companies for such incidents has to be rejected. With a strict policy to ban the cross connectors, a weak point of PV installation could be eliminated.

5 RELEASE OF SILICON PARTICLES AFTER A FIRE

Through fires on farm houses we got aware that, after a fire, a serious amount of silicon particles will be spread over a wide area in the direction of the wind. The farmer organizations of the state of Berne are concerned, that this area could be contaminated by the silicon particles.

Fire on a farmer workshop

We took the opportunity after a fire in April 2015 in Lanzenhäusern near Berne. A farmer workshop got into a fire after welding activities. The roof integrated "Solrif" - PV installation of about 60 kWp with 205 Wp (CNPV-205-BLK PV modules was completely destroyed. Through the strong west wind silicon particles would be distributed up to 2 km away from the site.

Figure 10: Workshop after the fire seen from east (position of the photographer first red circle on the map)

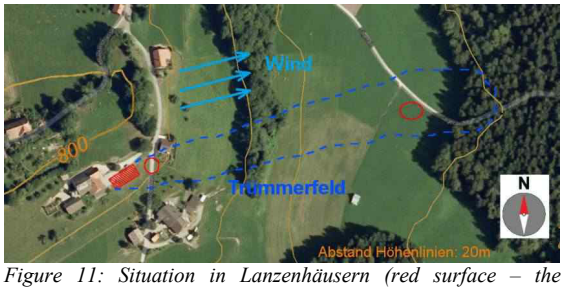

Figure 11: Situation in Lanzenhäusern (red surface – the workshop building) – first circle on the street position of the photographer/ second red circle: place of finding of silicon particles (see photo)

Figure 12: Silicon particle in the farmland – no further restriction for the use of the farmland

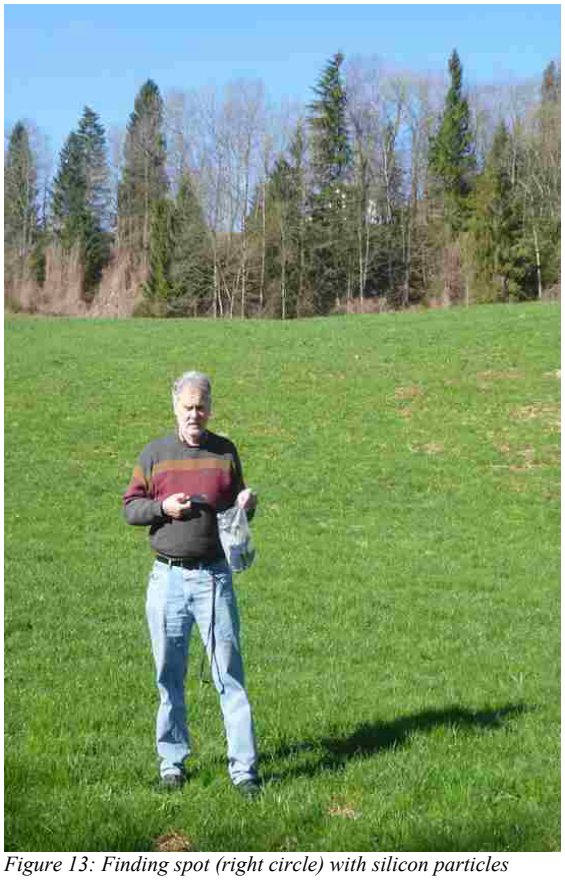

Figure 13: Finding spot (right circle) with silicon particles

In the debris all components and materials of the PV installation can be found. In the farmland only silicon particles could be found. Investigation of the particles with SEM showed that mainly Al/ Si and O could be detected. This is not a problem for a further use of the land for agricultural purposes.

Compatibility of silicon particles towards animals

To check the compatibility of the silicon particles towards animals, especially cows, we contacted Prof. Dr. med veterinarian Samuel Kohler from the agricultural department of the Berner Fachhochschule[8]. Problems with horses, sheep, goats etc. could be quickly excluded. After further investigations also the "cow" got a "green light". The silicon particles are so fragile that they will further smashed in the stomachs of the cow. Therefore silicon particle after a fire doesn't cause serious problems for the farmers.

Figure 14: Silicon particles for the „cow" – investigation – „green light" even for cows

6 RESULTS AND CONCLUSIONS

Fire prevention in PV installations can be done in a better way. Our investigations under PV installers showed that several influences are not well respected by the PV installers. We expect some more problems in the future. Cross interoperability of PV connectors is a serious threat for PV installations. Technical components as "light arc detectors" and "infrared-detection" of PV installations could help to prevent fires through the PV installations himself.

The training of fireman should be done seriously. The work of the PV laboratory and our new checklist we publish together with the insurance company Berner Gebäudeversicherung GVB leads the way.

Together with material specialist of the Berner Fachhochschule we investigated the mixture of elements in those particles with a scanning electron microscope SEM. We could show that only silicon and aluminum oxide from the back side of the solar cell can be found in the particles. These particles could be eaten by animals as horses, sheep, pigs and cows. All the animals, without the cows, choose their food very carefully and wouldn't eat such particles. The cows however would bring the particles into their stomachs. The silicon particles are so fragile that they will further smashed in the stomachs of the cow. Therefore silicon particles, after a fire, don't cause serious problems for the farmers.

7 ACKNOWLEDGEMENTS

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